PATENT SPECIFICATION

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(54) IMPROVED ROTARY HYDRAULIC MACHINES

(71) I, George Ernest Evans Warder, of 19 Vaughan Avenue, Stamford Brook, London, W.6 OXS, a British Subject, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to rotary hydraulic machines, that is to say to hydraulic pumps to which torque is applied and by which hydraulic fluid is delivered under pressure, or to hydraulic motors to which hydraulic fluid under pressure is supplied and which exert torque and to combinations of such pumps and motors either constructed as a single torque converter unit or separated by pipes.

It is an object of the invention to provide an improved rotary hydraulic machine, which acting as a pump will provide a smooth impulse-free flow of fluid and acting as a motor will provide a steady torque without wide fluctuations.

According to the present invention there is provided a rotary hydraulic machine including two concentric relatively rotatable disk members abutting each other at a common plane perpendicular to the axis of rotation a first of the disk members having a plane face which closes a concentric annular recess in the mating face of the second of the disk members, the first disk member having ports for the entry and exit of fluid from the annular recess and at least one abutment dividing the recess adjacent to the ports, and the second disk member having a plurality of radial slots containing respective vanes, the vanes having respective gateways and being radially slidable in the slots under cam control means so that in certain positions the vanes divide the annular recess and in other positions the recess is not restricted, the cam means being such that at all times at least two vanes divide the recess between entry and exit ports; the recess is not restricted in the vicinity of the abutment or abutments, and the vanes are only moved in the slots when passing a port.

The machine may further include an axially movable sleeve defining the bottom of the annular recess so that movement of the sleeve enables the swept volume of the machine to be adjusted. The machine may include one or more concentric annular recesses in the same disk member.

In order that the invention may be more clearly understood an example of a rotary hydraulic machine according to the invention will be described with reference to the accompanying drawings:

Fig. 1 illustrates a longitudinal cross section of the machine on radial lines XOX (Fig. 3). In Fig. 1 the upper half shews the volume control sleeve 23 withdrawn from the working chamber, that is to say in the full capacity condition, while the lower half shews said sleeve in its fully inserted position, that is to say in the cut off condition. In Fig. 1 the vanes 7, 15 are shewn in their radially fully displaced position, that is to say their gateways 34 coincide with the chamber 3 and clear the abutments 24, 25.

Fig. 2 illustrates a longitudinal cross section of said pump upon radial lines YOY (Fig. 3). In Fig. 2 the upper and lower halves shew the volume control sleeve 23 in the same respective positions as Fig. 1, and the vanes 18, 21 crossing the annular recess though still straddling the ports 45, 46.

Fig. 3 shews a transverse section of said pump on the line ZZ (Fig. 1) and also serves as a diagram for the explanation of the working cycle to follow. The left and right halves of the drawing Fig. 3 illustrate the rotor assembly 1, 2 in different rotational positions to be explained.

Fig. 4 is an "exploded" view illustrative of the component parts.

An example of a machine according to the invention illustrated comprises a rotor disk assembly 1, 2 mounted on a shaft 4, and provided with sixteen open-ended radial

slots 5 in planes containing the axis of the shaft forming guideways for vanes 7 to 22, said vanes being made a neat sliding fit therein. The assembly is surrounded by a casing 6 forming a fluid space 62 closed by a stator assembly 27, 28 at the running interface. The fluid space 62 is connected with the space 63 thus equalising the fluid pressure acting upon the opposite ends of the vanes, said spaces in the construction illustrated being interconnected via passage 57 with a fluid return space 47.

An annular recess 60 (Fig. 2) in the face of the rotor 1 collects leakage fluid from an annular recess 52 containing fluid under pressure from the clearance volumes for the vanes (see below) and returns it via passage 61 to space 62 and to a fluid return space 47.

A deep annular recess 3 in the rotor 1, 2 is partly occupied by a swept-volume control sleeve 23.

Radial slots 5 in said volume-control sleeve match those in the rotor, but are made somewhat deeper so that when said sleeve is inserted in the annular recess 3 with its slotted face flush with the slotted face of said rotor a working clearance for the vanes is provided containing fluid in operation.

The bottoms of said slots in the volume-control sleeve 23 are each provided with a passage 54 (Fig. 2) communicating with the bottom of the annular recess 3 to relieve said clearance volumes and to allow the volume-control sleeve to slide to and fro in the annular recess.

The vanes have respective gateways 34 so proportioned as to clear abutments 24, 25 with a working clearance as the "lintel" of said gateway beyond the axial depth of said annular recess and a somewhat larger clearance for the inner and outer arcuate faces of the abutments 24, 25.

The vanes have respective lugs 33 constituting cam followers projecting into a conjugate cam groove 44 formed in the face of the stator 27.

The stator comprises two concentric parts 27, 28 permanently assembled, with a casing 29 and an endshield 30; the parts 27 and 28, 29, 30 being assembled and located in alignment by a multiplicity of drawbolts and nuts 37, 38 spaced upon a pitch circle, two of which are "fitted".

Said stator components 29, 30 respectively contain bearings 31, 32 for the shaft 4, and the rotor assembly 1, 2, 4 has plane opposite faces which run at working interfaces with those of the stator assembly 27, 28, 29 and the endshield 30.

The outer face of the stator assembly 27, 28 is covered by a backplate 39 which incorporates the pipeline connexions.

Between members 27, 28 are formed open-ended slideways 35, 36 at places diametrically opposite containing two abutments 34, 35 made to move therein with a neat sliding fit, the arcuate inner and outer walls of said abutments matching the inner and outer radii of the annular recess 3.

The abutments 24, 25 project from the slideways 35, 36 into the working chamber to divide the annular recess 39 into two half-annulae each crossed by eight vanes.

Said abutments 24, 25 are urged axially against the slotted face of the volume control sleeve 23 by low-rate springs 26 pressing against the back plate 39.

An annular recess 40 in the backplate 39 provides hydraulic intercommunication between the slideways 35, 36, said recess also being connected by a passage 41 (Fig. 2) with the discharge or pumped pressure via passage 48 which pressure acts on the back faces of the abutments. The sliding end-faces of the abutments 24, 25 are thus urged against the slotted face of the volume control sleeve 23 by the discharge pressure and the force they exert is opposed by the control fluid-force.

The stator component 27 has a conjugate cam groove 44 effecting radial displacement of the vanes in turn from two inner positions at which a vane is static radially and each vane crosses and divides a half-annulus as shewn in Fig. 2 to two outer radially static positions at which at which the gateway 34 in each vane in turn straddles the abutments as shewn in Fig. 1, and allows the vane to pass.

The active portions of the conjugate cam groove 44 are of sinusoidal form to minimise the accelerating and decelerating force acting on the vanes.

The stator member 28 has at each side of each abutment slideway 35, 36 arcuately elongated ports 45, 46 (Figs. 2, 3, 4) which extend for sufficiently large arcs as to straddle the vanes during their radial motion substantially to equalise the pressures on opposite faces of the vanes during their displacement. Said ports communicate via passages 47, 48 respectively with suction or return fluid pipelines 42, 43 which may or may not be arranged coaxially for a particular application.

In order to ensure that the volume control sleeve 23 and the abutments 24, 25 riding upon its slotted face float freely axially in their mating components and take up positions resulting in balance between the forces exerted by the control and pumped discharge pressures, well known hydrostatic bearings (not shewn) may be applied to the inner and outer cylindrical surfaces of the volume control sleeve and to the abutment housings.

The cycle of operations is as follows:

With reference to Fig. 3, the left hand half of the cross section shews a rotational position of the rotor slightly before the position shewn in the right hand half of the cross section, so that the vane 7 appears in two places; in its fully displaced outer radial position in which its gateway 34 is coincident with the annular recess 3, and in angular coincidence with the abutment 25.

Considering the half annulus illustrated in the left hand half of Fig. 3, vane 16 has just passed the abutment 24 in the direction of rotation shewn by the arrows, and is meantime idle (the term "idle" is used to indicate that a vane is for the time being not actively passing fluid from the inlet to the outlet of the machine) with its gateway 34 still straddling the working recess 3 and prior to its displacement radially inwards under the action of the conjugate cam 44.

Vane 18 is at this instant in the cycle nearly fully displaced radially inwards to its working position but is still straddling the inlet port 45 and therefore idle. At this point in the cycle vanes 19, 20 are in position across the half-annulus, vane 19 exerting suction upon the inlet compartment RRR and port 45, and vane 20 expelling discharge pressure fluid from the compartment PPP to the outlet port 46. The half annulus is thus divided into three compartment namely a return or suction compartment RRR bounded by the abutment 24 and vanes 19; a "dead" compartment full of fluid trapped between vanes 19, 20 and a pressure or discharge compartment PPP open to the outlet port 46 and bounded by vane 20 and the abutment 25.

The pressure difference between inlet and outlet is thus subdivided into two stages by vanes 19, 20 and enclosed by the greater thickness of the abutments 24, 25 dividing adjacent compartments in each half annulus subject to discharge pressure and suction respectively.

The right hand half of Fig. 3 illustrates an instant in the cycle at which the rotor is advanced in the direction of rotation to a point at which the working half annulus 3 is divided into four compartments, namely: a suction or return compartment RRR open to the inlet port 45 bounded by the abutment 25 and a vane 10 which is exerting suction on the hydraulic fluid in compartment RRR or being urged by the back pressure or static head in the return pipeline through passage 47 and port 45; two "dead" compartments D, D trapped between vanes 10, 11 and 11, 12 subdividing the pressure difference between inlet and outlet; and a pressure or discharge compartment PPP open to the outlet port 46 and the passages 48 bounded by the vane 12 and abutment 24. Vanes 7, 8, 9, 13, 14, 15 are meantime inoperative.

On further rotation of the rotor successive vanes in turn take over the duty of exerting suction upon the ingoing fluid as they leave the end of the inlet port 46, so maintaining the discharge pressure until relieved of this duty by the following vane upon straddling said outlet port. When vane 11 reaches the position of rotational coincidence with the abutment 24 one cycle is complete, there being in this construction two simultaneous cycles per revolution Thus at least one "dead" volume of fluid trapped between vanes and carried round each working half annulus divides outlet pressure from inlet at all times during the cycle, making possible higher outlet pressures in a pump or inlet pressures in a motor than if no such "dead" volume were provided.

The arcuate length of the cam action for radial displacement of the vanes is determined by the requirement that the vanes only undergo displacement when they are not subject to fluid pressure difference on their opposite faces, i.e. when they are bridged by the inlet or outlet ports. The cam action for radial displacement of the vanes occurs between 10 and 60 degrees before and after each abutment relative to its centre line that is over an angle of 50 degrees of arc of travel.

The portion of a port adjacent to an abutment is always straddled by a gateway as a vane passes, so the elongation of a port in this direction need only comply with the requirement of cross sectional area which may equal that of the working annulus and one half of that of the pipeline thus resulting in constant velocity of the fluid through the machine i.e. the tangential velocity of the vanes.

It should be noted that no cut-off of fluid occurs as the vanes pass the ends of the ports, nor does the flow of fluid from or to the ports cease at any point in the cycle, the fluid flowing unidirectionally with minimum change of kinetic energy and heating.

One form of hydraulic control system for constant pressure discharge with variable volumetric demand for example will be described. Force due to a control pressure acts upon the unslotted end face of the volume control sleeve 23 (less the portions of the edges of all the vanes contained in the slots) and reacting on the stator end-shield 30, the annular recess 52 providing intercommunication.

The mean force exerted upon the slotted face of the volume control sleeve 23 forming one wall of the annular chamber is balanced by said control pressure at any constant pressure of discharge so that the

area of the uninterrupted face of said sleeve always exceeds that acted upon by the discharge pressure the machine will reduce itself to zero output unless the control pressure is reduced. A pressure divider comprising two capillary tubes 41, 57, respectively connected to the discharge and suction pressures are connected via the passages 51, 55 with the annular recess 52 thence with the effective area of the volume-control sleeve 23.

A bypass passage 58 from the control pressure volume is closed by a spring-loaded relief valve 49, said valve being set to lift at a pressure depending on the ratio of the discharge pressure required to the balancing control pressure needed for equilibrium, providing a preset bleed reducing the control fluid pressure.

Said capillaries provide damping to reduce oscillation of the volume control sleeve whose axial vibratory resonance is far lower than that of the variation in force on its slotted face due to cyclic variation in area exposed to the discharge pressure during each revolution.

The volume control sleeve need not be moved hydraulically as described, but by mechanical means under manual or servo control, while the vanes may be displaced by hydraulic means acting directly on their ends or by cylinder-and-piston devices acting thereon or by a single cam with spring return instead of the conjugate cams described.

Rotary hydraulic machines according to this invention may be constructed as fixed swept-volume pumps or motors. The swept volume control sleeve described is omitted in this construction and the abutment of abutments are fixed or spring and fluid pressure loaded sliding in the plane-faced disk and riding on the slotted face of the bottom of the annular recess in the rotor.

Rotary hydraulic machines according to the invention may be constructed with two or more annular recesses which may be conveniently of the same radial width and therefore of differing swept volumes. Each and all of said recesses are crossed radially by a common set of vanes each provided with spaced gateways to clear abutments dividing the several recesses, the abutments being arranged in sets in radial alignment; said vanes are displaced radially in turn by one set of devices such as the conjugate cams described to clear sets of radially aligned abutments simultaneously.

Such machines provide hydraulic pumps or motors variable in swept volume in steps at will by the operation of valves selectively connecting the inlet ports of each of the several chambers to the pressure and return pipelines of the associated hydraulic fluid system and interconnecting the ports of the chamber or chambers rendered idle for the time being and isolating it or them from one of the pipelines occasioning little loss of power due to circulation of fluid, or the abutments may be withdrawn from idle chambers with reduction of power loss.

Having now particularly described and ascertained the nature of my said invention, and the manner in which it is to be performed,

WHAT I CLAIM IS:—

1. A rotary hydraulic machine including two concentric relatively rotatable disk members abutting each other at a common plane perpendicular to the axis of rotation, a first of the disk members having a plane face which closes a concentric annular recess in the mating face of the second of the disk members, the first disk member having ports for entry and exit of fluid from the annular recess and at least one abutment dividing the recess adjacent to the ports, and the second disk member having a plurality of radial slots containing respective vanes, the vanes having respective gateways and being slidable radially in the slots under the control of cam means so that in certain positions the vanes divide the annular recess and in other positions the recess is not restricted, the cam means being such that at all times at least two vanes divide the recess between entry and exit ports; the recess is not restricted by the vanes in the vicinity of the abutment or abutments and the vanes are only moved in the slots when passing a port.

2. A machine according to Claim 1, further including an axially movable sleeve in the recess having slots aligned with slots in the second disk member to allow movement of the vanes, the sleeve against which the or each abutment presses defining the bottom of the annular recess, the or each abutment being movable to accommodate movement of the sleeve, the movement of the sleeve enabling the swept volume of the machine to be adjusted.

3. A machine according to Claim 2, including mechanical or hydraulic means for moving the sleeve.

4. A machine according to Claim 2 or 3, including resilient means for urging the or each abutment into contact with the sleeve.

5. A machine according to any preceding Claim in which the cam means comprises a groove in the plane face of the first disk member, each vane having a lug which projects into the groove.

6. A machine according to any preceding Claim, including two or more abutments and two or more sets of entry and exit ports.

7. A machine according to any preceding Claim, including one or more further concentric annular recesses in the mating face of the second disk member with associated entry and exit ports in the first disk member radially aligned with the entry and exit ports of the first mentioned annular recess there being one or more abutments provided on the first disc member adjacent to the ports and the vanes being provided with one or more additional gateways corresponding respectively to the further recess or recesses, so that the further recesses can operate in a similar manner to the first mentioned recess.

8. A machine according to any preceding Claim, wherein the first disk member is a stator and the second disk member is a rotor.

9. A rotary hydraulic machine substantially as herein described with reference to the accompanying drawings.

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1295473 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG. 1.

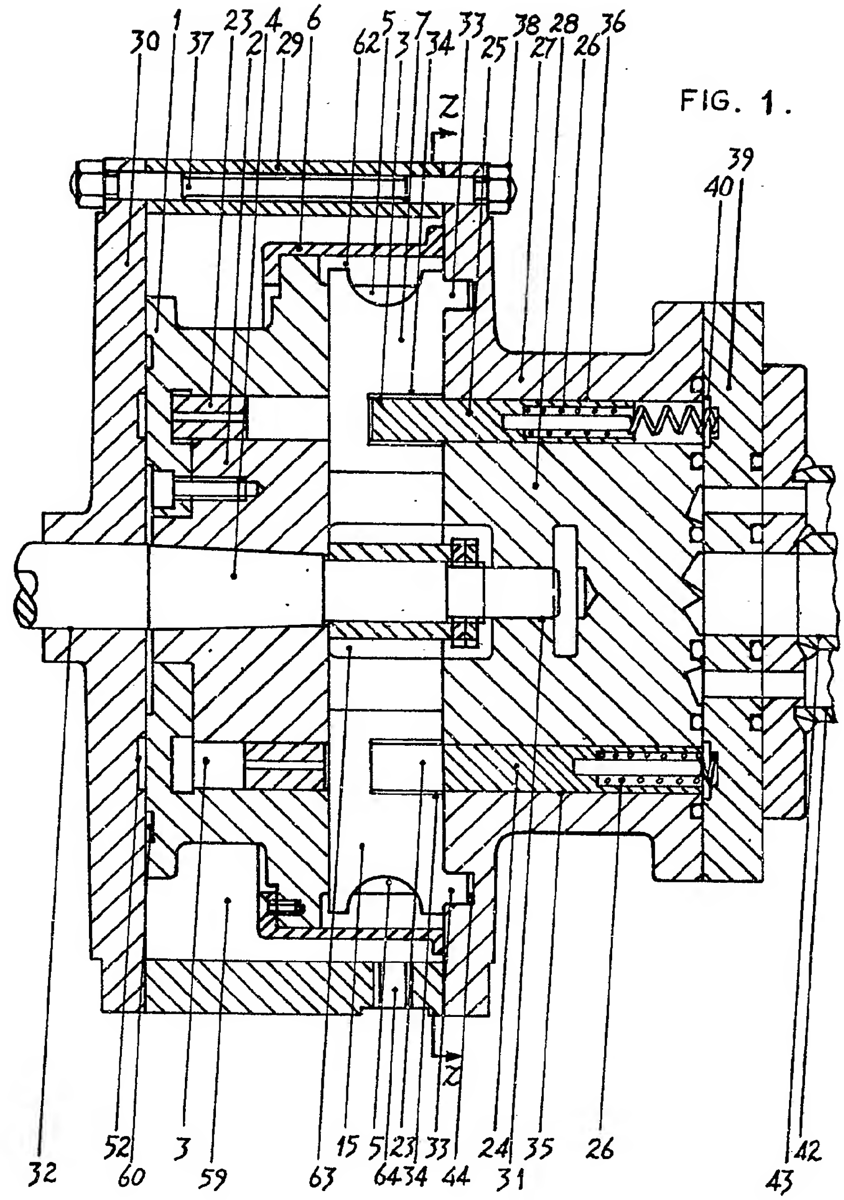

FIG. 2.

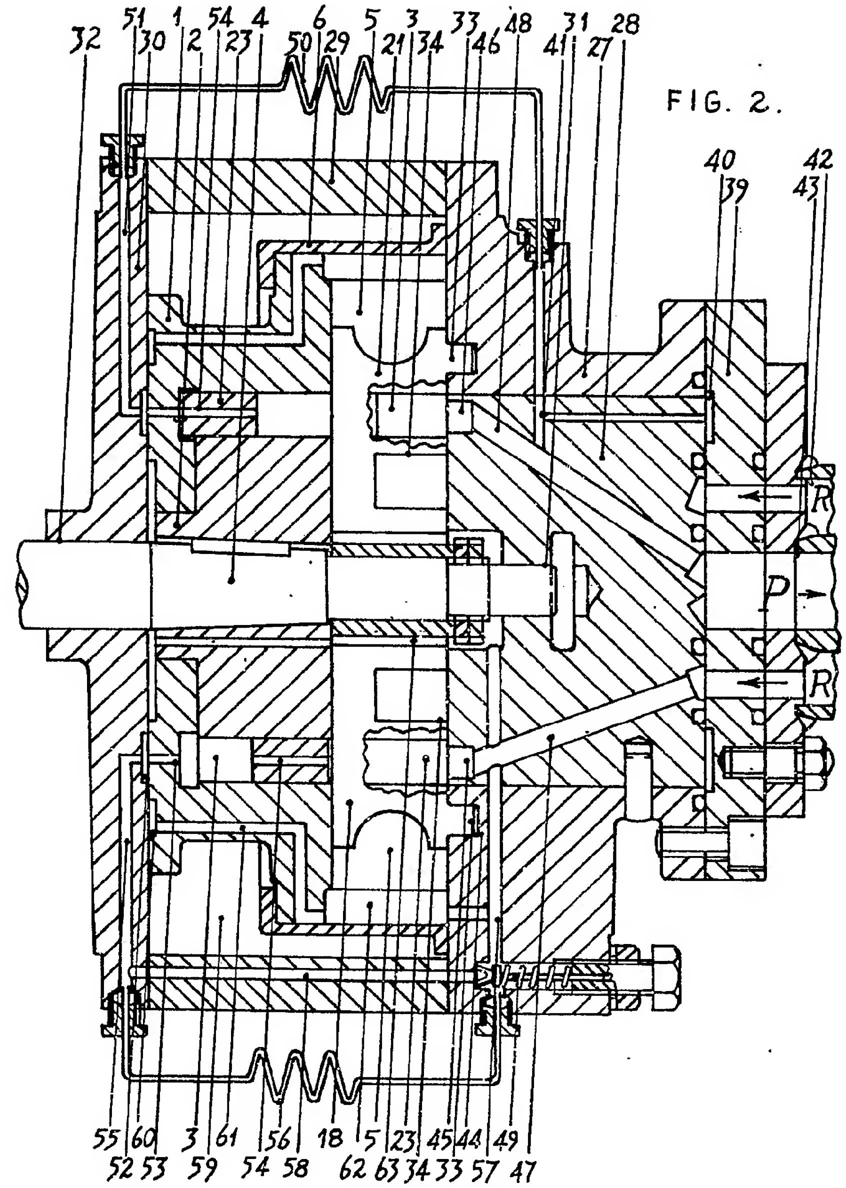
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FIG. 3.

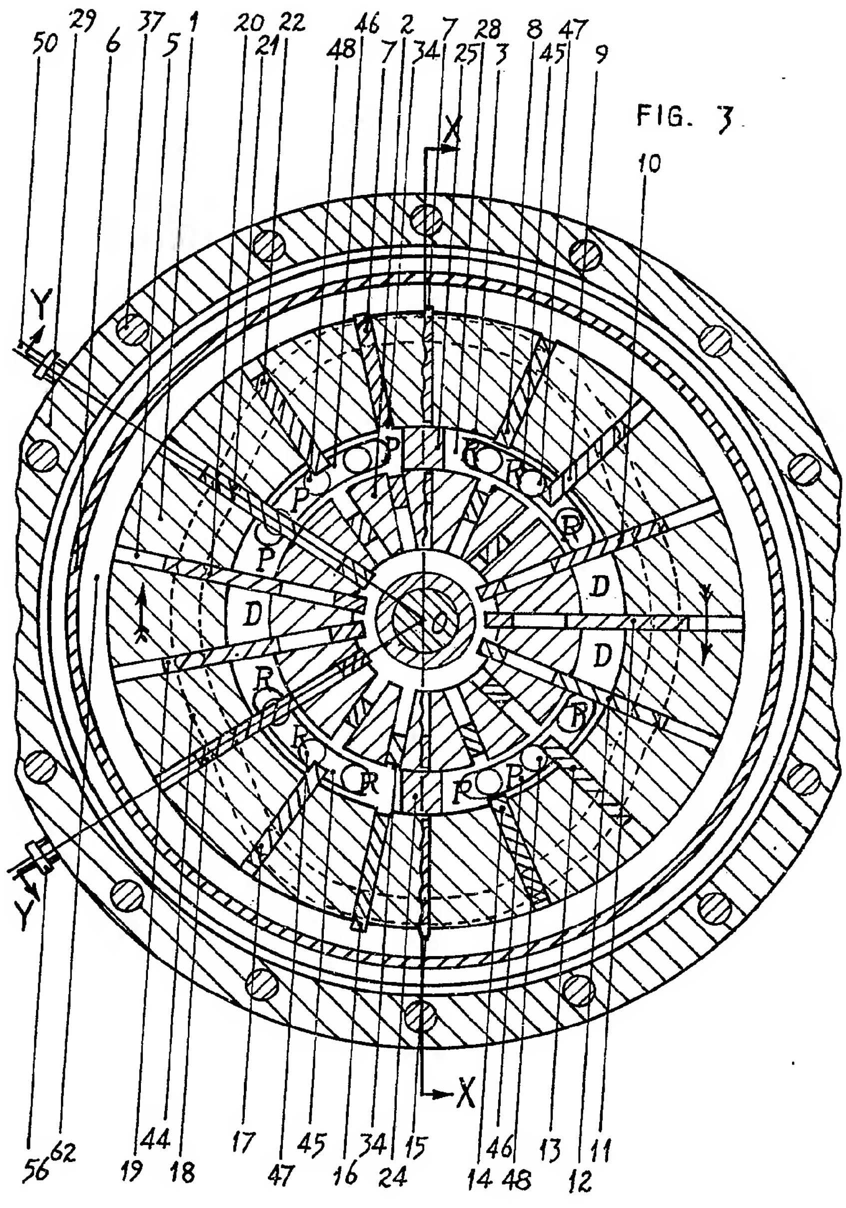
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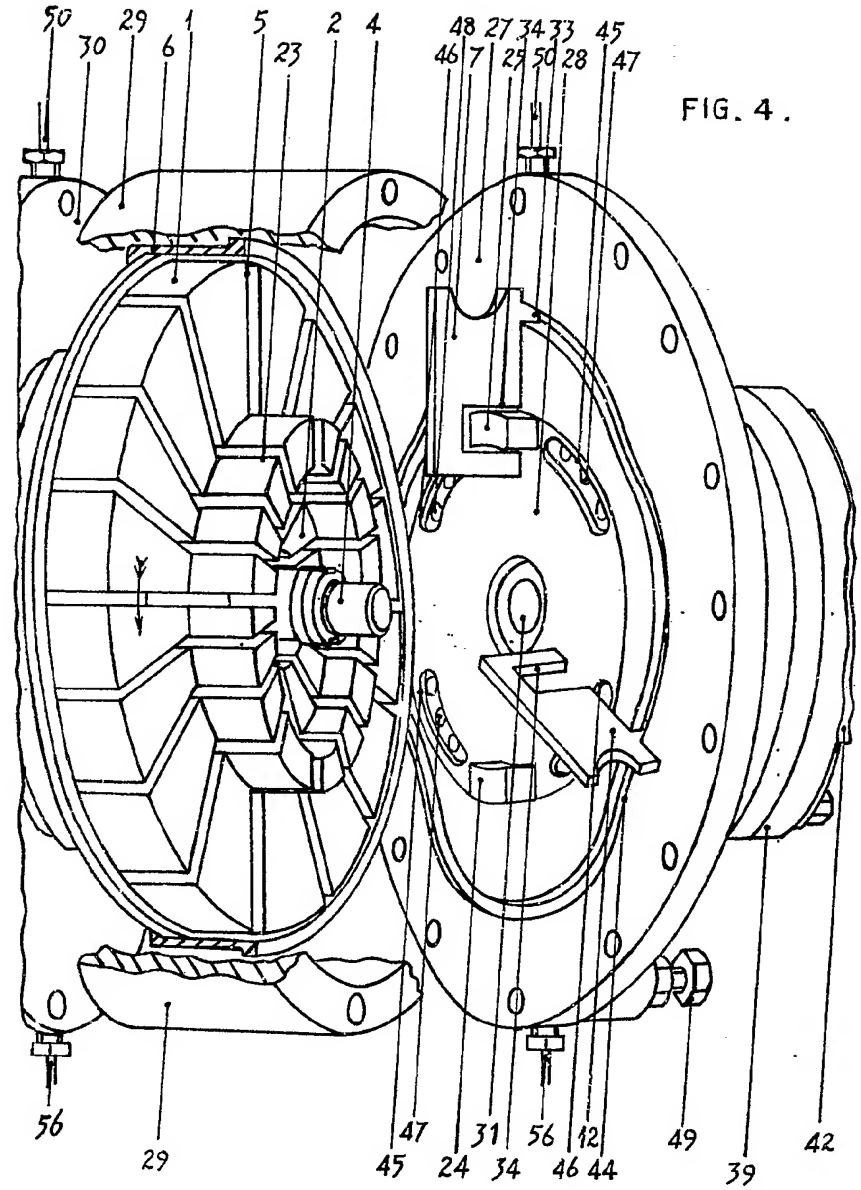
FIG. 4.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